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Coherent Lidar Design and Performance Verification

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Summary of Progress

The performance of coherent Doppler lidar in the weak signal regime was determined by computer simulations using the best velocity estimators. Threshold signal levels were defined for useful and good data based on the fraction of the estimates that were random outliers due to the fading in the return signal. The dependence on threshold signal level S with the number of lidar pulses N used for each estimate produced simple empirical curves of the form $S=KN^{-a}$ were $a\approx0.75$ for small N and $a\approx0.5$ for large N. The statistical accuracy of the good velocity estimates at the threshold signal level was approximately constant as a function of N. This simplifies system design analysis. For space based applications, performance was investigated using the Capon estimator with various levels of wind turbulence for a 2 and 10 micron lidar. Simple scaling laws for the threshold signal level with pulse accumulation were produced.

Analysis of 2 micron Doppler lidar data from a new experiment is underway. This data is from a diode-pumped solid-state lidar with low pulse energy which is ideal for investigating the low signal regime. Preliminary results indicate excellent agreement with simulations for the fraction of outliers. The estimation error of the good velocity estimates is more difficult to determine because of the large data set required for statistical reliability. Preliminary results are within 15% of ideal simulations. For a 10 km horizontal path, velocity accuracy of better than 0.2 m/sec was demonstrated using 100 pulses of data. The factor of 10 improvement in system sensitivity was verified for these boundary layer conditions.

Improved algorithms for extracting the performance of velocity estimators with wind turbulence included were also produced. These algorithms permit robust parameter estimation for a wide variety of conditions. They were applied to many cases by Brian Lottman, the graduate student supported by NASA for the summer. Simulations of the effects of refractive turbulence on laser propagation were also conducted in collaboration with Reg Hill of NOAA. This work produced new techniques for estimating the parameters of the atmospheric refractive index spectrum, which is required for any optical remote sensing instrument. This is particularly important for ground-based testing of lidar performance.

A no-cost extension was requested to complete a project for the Space Lidar Working Group meeting in Feb.

Recent Publications

"Coherent Doppler Lidar Performance Based on Computer Simulation and 2 Micron Doppler Lidar Data," R. G. Frehlich, S. M. Hannon and S. W. Henderson, ESA Doppler Wind Lidar Workshop, 20-22 Sept. 1995, ESTEC, Noordwijk, The Netherlands.

"Simulation of coherent Doppler lidar performance in the weak signal regime", R. G. Frehlich, submitted to J. Atmos. Ocean. Tech.

"Coherent Doppler Lidar Measurements of Winds", invited book chapter for "International Trends in Optics" published by the International Commission for Optics.

"Onset of strong scintillation with application to remote sensing of turbulence inner scale", R. J. Hill and R. G. Frehlich, Applied Optics, in press.

"Effects of wind turbulence on coherent Doppler lidar performance", Rod Frehlich, submitted to J. Atmos. Ocean. Tech., revised in 1995.

"Simulation of Wave Propagation in Three-Dimensional Random Media", Wm. A. Coles, J. P. Filice, R. G. Frehlich, and M. J. Yadlowsky, Applied Optics Vol. 34, 2089-2101, (1995).

"Comparison of 2 and 10 Micron Coherent Doppler Lidar Performance", Rod Frehlich, J. Atmos. Ocean. Tech., Vol. 12, 415-420, (1995).